ARTI- Air Conditioning and Refrigeration Technology Institute

Flexible and Adaptive HVAC Distribution Systems for Office Buildings

Key Findings

June 5, 2001

2001 Energy ‘Walking on Air ‘presentation

Center for Building Performance and Diagnostics

Oak Ridge National Laboratory

Completed Tasks

- Collected and reviewed 115 national and international references
- Interviewed 10 leading engineers
- Collected materials from 20+ manufacturers
- Created a database of 250+ underfloor air projects worldwide
- Completed a draft report with figures

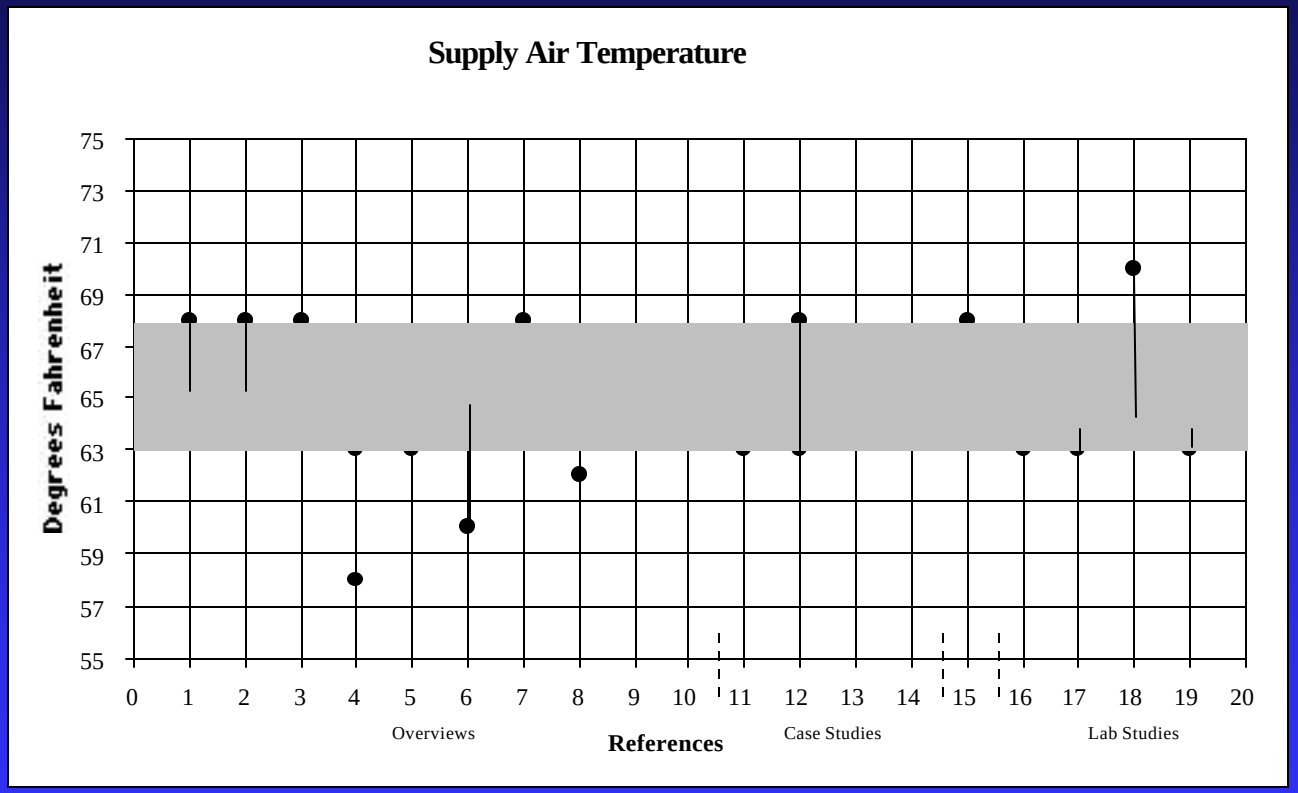
Flexible and Adaptive System Types

- **Pressurized Plenums**
  - unducted or partially ducted
  - fully ducted
- **Neutral Plenums with Distributed Fans**
  - Floor fans, ducted and unducted
  - Desk fans, ducted and unducted
- **Displacement Ventilation**
  - UF Air and water-based thermal
  - UF Air and air-based thermal
- **Ceiling-based Flexible HVAC**
  - Ceiling ventilation only, separate thermal
  - “Dual” duct system for ventilation & thermal
  - Microzoning and relocatable zoning.

Generation - Central System Issues

- Most North American underfloor systems are all-air based for cooling and ventilation, however, the separation of thermal/ventilation and ambient/task improves performance.
- Perimeter conditioning should be separate, with subdivided-air, split air-water, or neutral facades.
- Supply air temperatures are typically 63-68F, and central systems may be smaller, with greater use of economizer.
- Relative humidity control is critical.

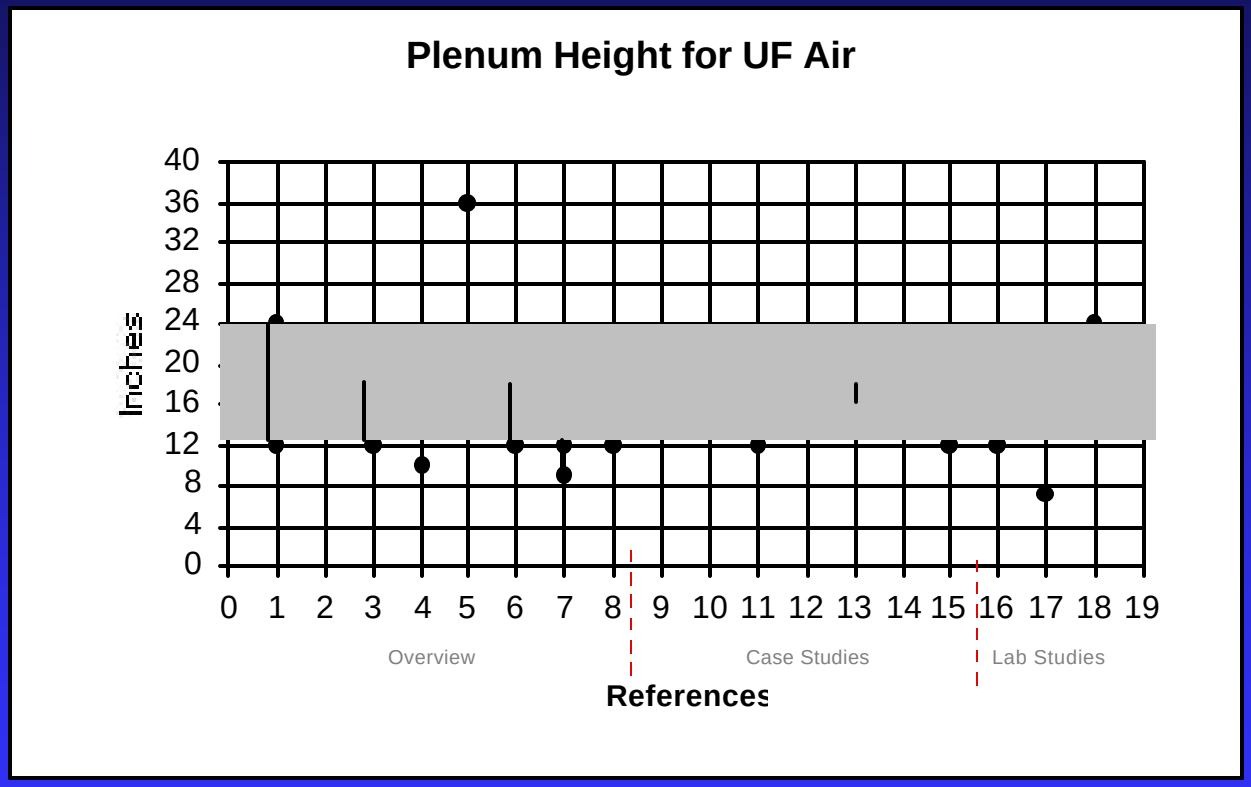
Supply Air Temperatures

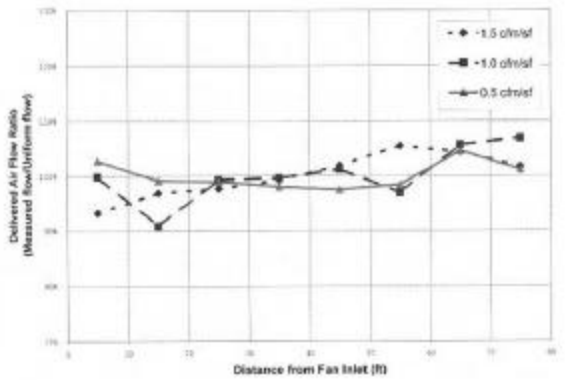


Distribution – Plenum Design Issues

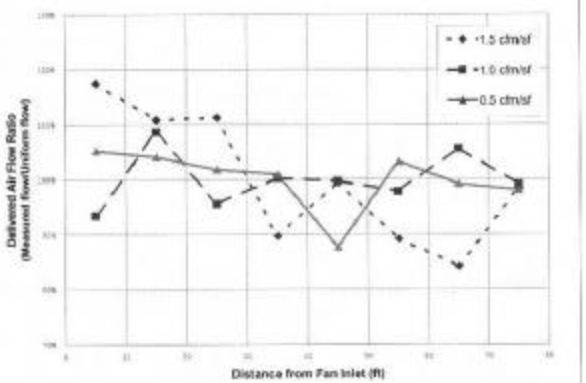
- Most systems are low-pressure open plenums (15-25 Pascals, 0.1 in/water static pressure).
- Underfloor plenums are typically 12”-18”, but effective systems can be designed from 7”-36”.
- Floor to floor heights do not have to increase.
- Recommended distance from vertical riser/supply is 30 feet (with a maximum at 70 ft.).
- Flywheel cooling is effective, but moisture must be controlled.

Plenum Height

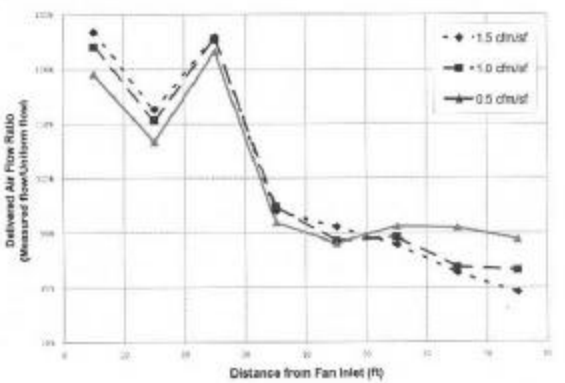




Air flow ratio comparison
for 7-inch plenum



Air flow ratio comparison
for 3-inch plenum

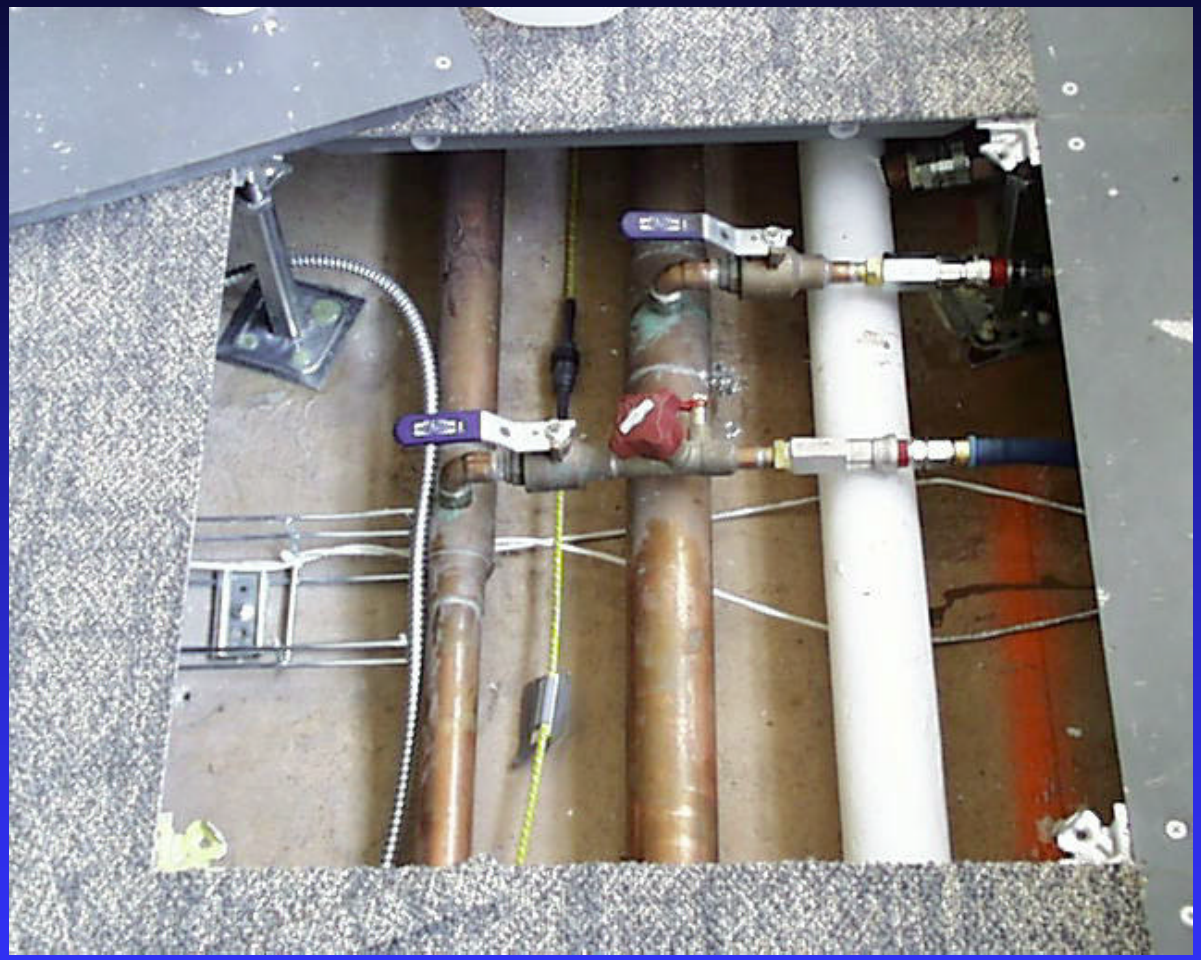


Air flow ratio comparison
for 2-inch plenum

Center for the Built Environment
"How Low Can You Go?"
Air Flow Performance of Low-Height
Underfloor Plenums

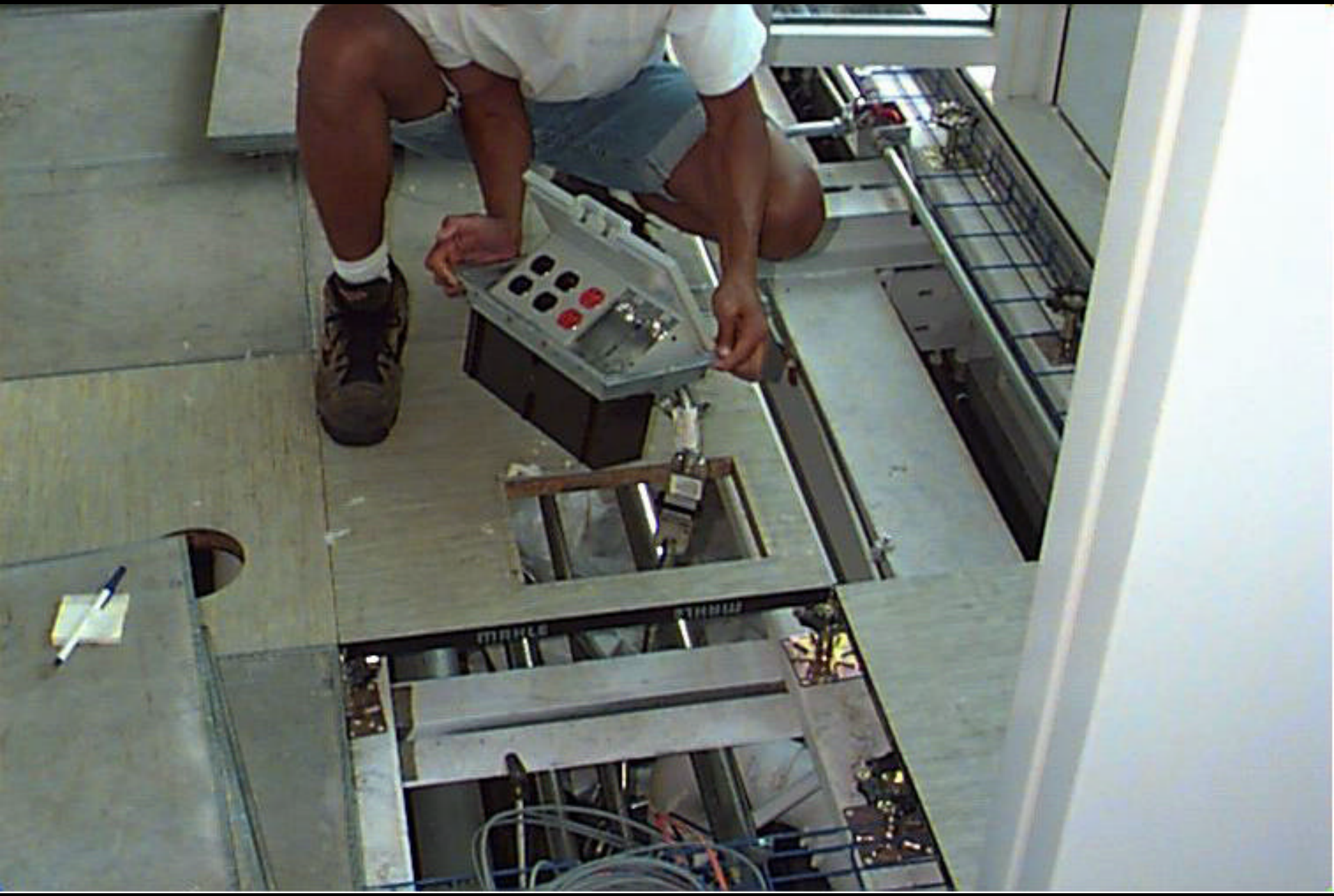
UC Berkeley laboratory tests identify significant decay in air flow rate when the plenum is below 7 inches.

Challenge the industry to develop fully prototyped, grid-and-node solutions



Terminal Units - Diffuser Design Issues

- Swirl diffusers ensure mixing/stratification and outperform linear or jet diffusers.
- Supply air velocity should be 80-100 cfm per diffuser (38-47 l/s) to avoid drafts & noise.
- Diffuser density should not be less than 1-2 per person or 1 per 100 sq. ft, with strategies for ambient conditioning.
- Desktop diffusers offer the best air quality and thermal control. Floor diffusers should be controllable or 2.5 feet away to avoid drafts.



Individual Control Alternatives

- Individual control of diffuser location and density is required to deliver flexible and adaptive HVAC for organizational change/ churn.
- Individual control of air volume/speed, air direction, and temperature (mixing) = high thermal satisfaction.
- Individual control of air filtration, outside air content, and natural conditioning = high air quality satisfaction.
- Without room pressurization, windows can be opened.

JC’s PEM desktop diffusers combined with neutral plenum offers individual control of air speed, air volume, horizontal and vertical air direction, (mixing) air temperature with 2.8% measured impact on productivity if disabled.

Systems Integration & Process Issues

- At least 5 disciplines must be assembled to design “the plenum real estate challenge”- HVAC,connectivity, fire, structure, interiors.
- Industrial partnerships are emerging to integrate access floor tiles, carpet tiles, power connections, and diffusers for reconfigurability without waste.
- Integrate building enclosure to eliminate perimeter thermal conditioning and maximize natural conditioning.

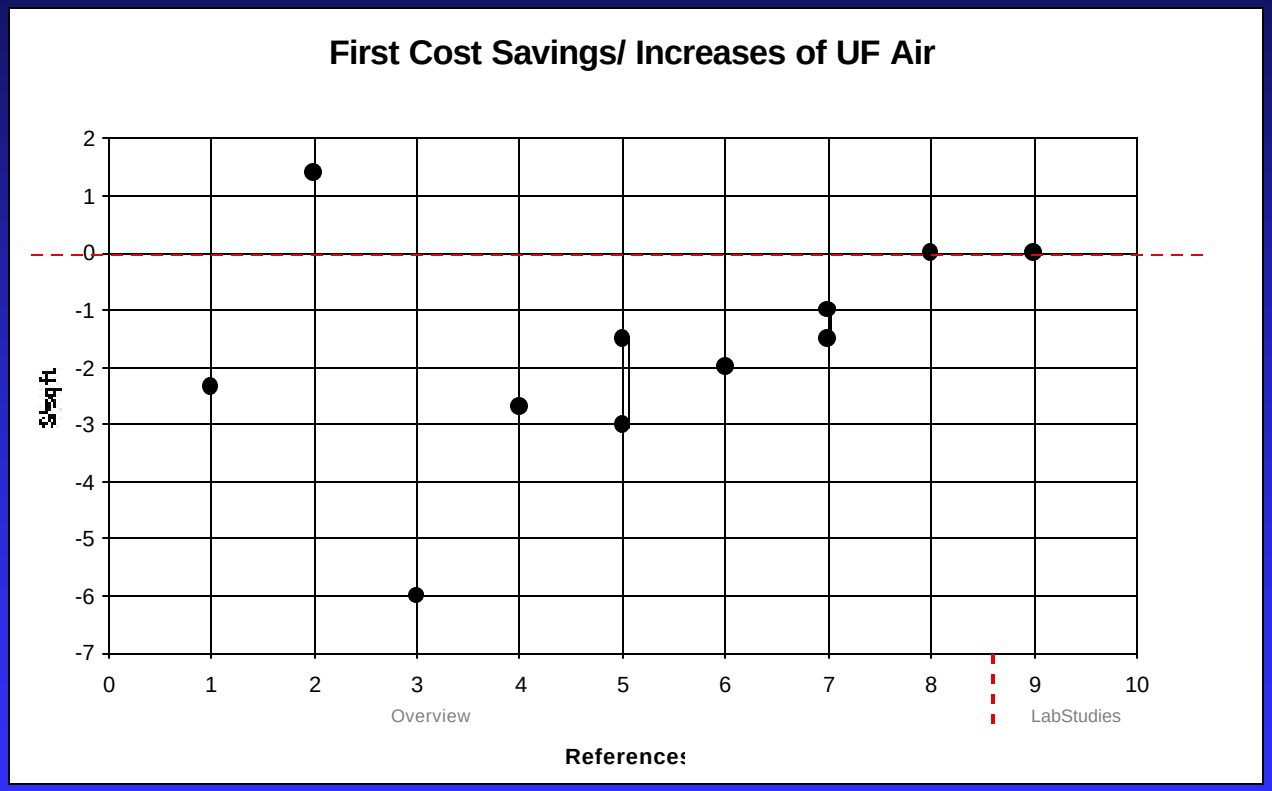
Performance Concerns

- While new projects have no first cost increases, retrofit projects may see 5-20% higher costs.
- Cooling capacitance may be limited to 40w/m2, without secondary systems.
- Warmer supply air temp. reduces chiller capacity to dehumidify (need separate system).
- Stratification and possible drafts challenge thermal comfort standards.
- Relative humidity/ IAQ concerns, but no reports.

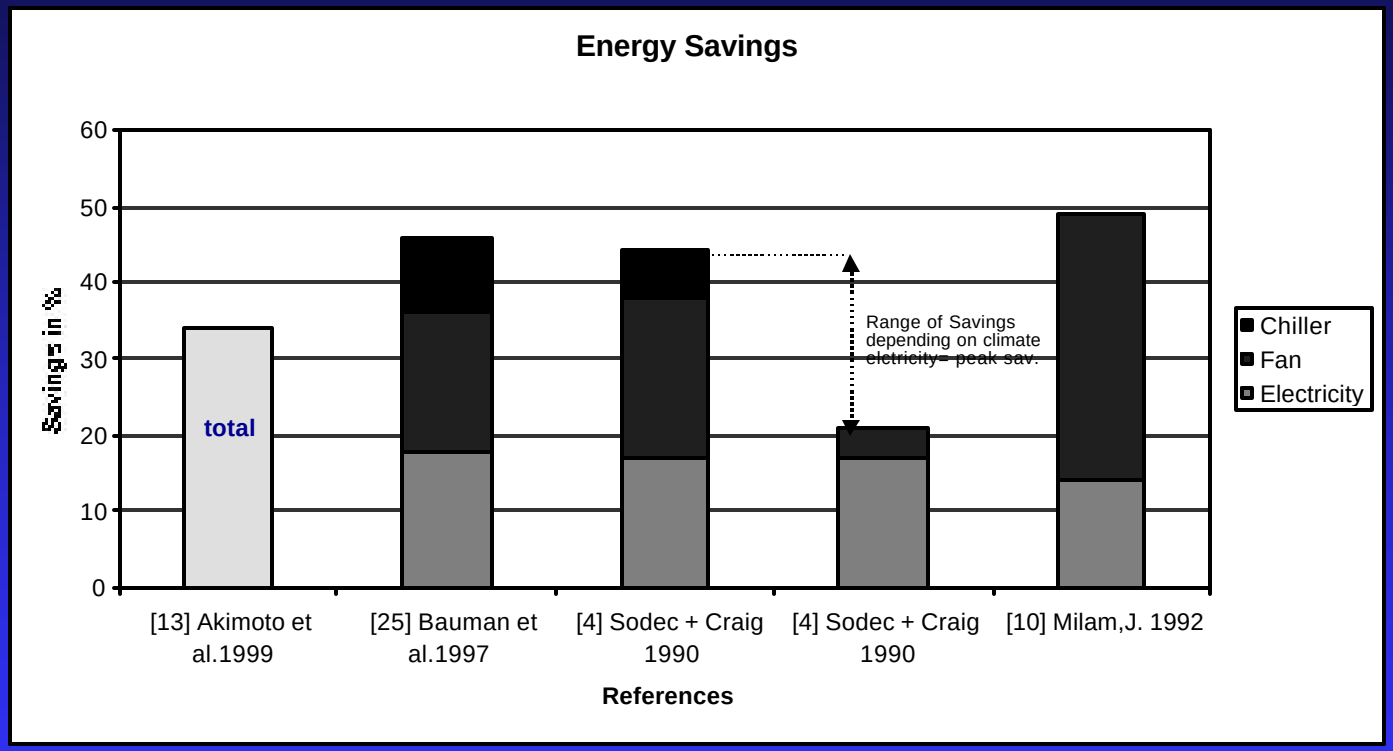
Performance Gains

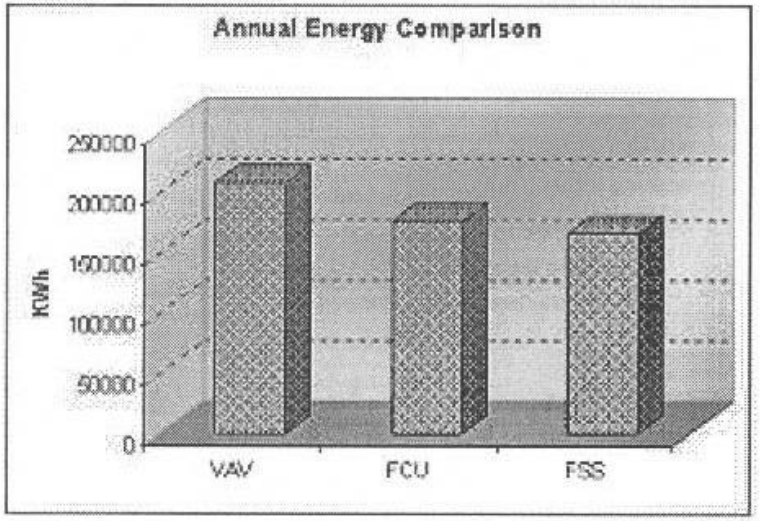
- In new construction, first costs of UF Air are equal or lower than ceiling systems.
- Churn cost savings can be from $100 to $500 per person moved.
- Productivity gains with task air have been measured at 2.8% (RPI/ Westbend study).
- IAQ /Ventilation effectiveness is increased by 20%.
- Energy savings are 20-25% due to reduced fan power, increased chiller efficiency, economizer, task shut-down, and flywheel cooling.

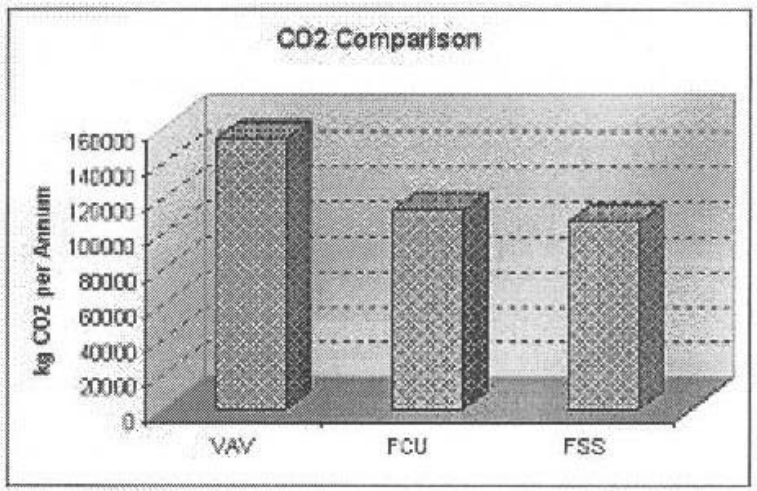
First Cost Savings



Energy Savings







VAV: variable air volume system
FCU: fan coil unit
FSS: Flexible Space System underfloor air

Thomas, Glan Blake
Advanced Ergonomic Technologies
study by Building Simulation Ltd.

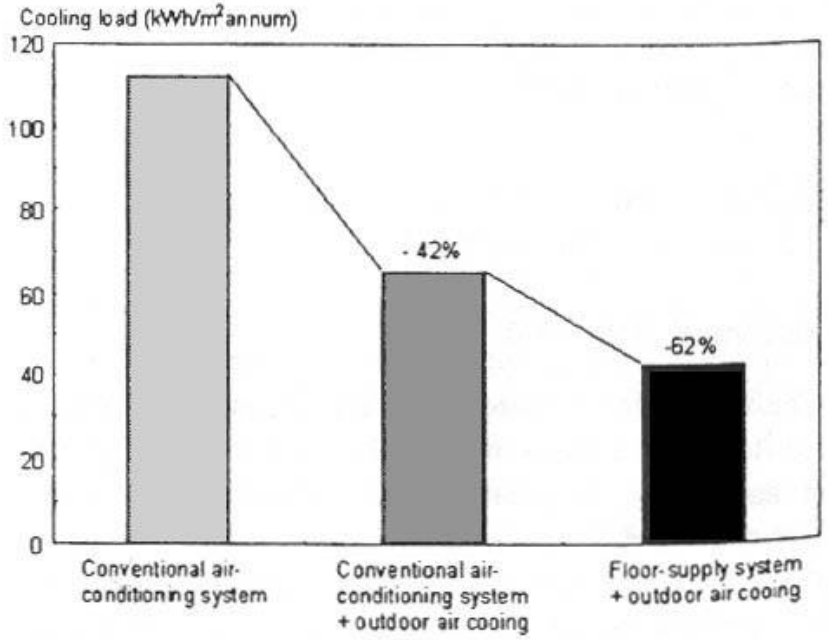


Figure 8 Energy conservation effect on outdoor air cooling.

Akimoto, Takashi et. al.
"Floor-Supply Displacement
Air Conditioning:
Laboratory Experiments"

Messages to the Industry

- Market underfloor air systems as part of the raised floor package, improving plenum subdivision/ zone modifiability and sub-systems adaptability.
- Develop robust HVAC B-to-C assemblies from generation to end-user control to ensure cost-effective performance.
- Develop plug and play local cooling strategies for relocatable conference rooms and teaming spaces.
- Recognize the un-encumbered ceiling and develop acoustic strategies, up-lighting, return air, and sprinkler system integration.